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1. Your reference

2. Patent application number *(The Patent Office will fill this part in)* — 0406084.4

3. Full name, address and postcode of the or of each applicant *(underline all surnames)*

Prof. Norman West Bellamy
95 St. Martins Rd.
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Patents ADP number *(if you know it)* — 0359135 1001

If the applicant is a corporate body, give the country/state of its incorporation

4. Title of the invention

Lining Pipelines using Thermoplastic Sheet and Strip.

5. Name of your agent *(if you have one)*

"Address for service" in the United Kingdom to which all correspondence should be sent *(including the postcode)*

~~95 St. Martins Rd.~~
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Form 51/77 filed 8.4.05

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Country	Priority application number *(if you know it)*	Date of filing *(day / month / year)*

7. Divisionals, etc: Complete this section only if this application is a divisional application or resulted from an entitlement dispute (see note f)

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Continuation sheets of this form	0
Description	7
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Signature(s) N. W. Bellamy   Date 17-3-04

12. Name, daytime telephone number and e-mail address, if any, of person to contact in the United Kingdom

Prof. Norman W Bellamy
Tel/Fax. 024-76415466

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DESCRIPTION

LINING PIPELINES USING THERMOPLASTIC SHEET AND STRIP

This invention relates to the lining of pipelines with a close fit lining with structural properties to prevent leaks and eliminate problems arising from corrosion and age.

Leakage is a major problem to the gas and water authorities and repairs or replacement of gas, water and sewage pipes are expensive operations. Leakage from gas pipes is dangerous and leakage from water pipes can average over 30% between reservoir and tap. Many pipelines are in need of refurbishment and the authorities generally seek long term solutions rather than piecemeal repairs. Thermoplastics such as polyethylene are the current preferred materials for relining the gas and water networks and can have planned operational lifetimes of at least 50 years. However, the absence of suitable lining methods for large diameter pipes mean that expensive replacement solutions often have to be implemented.

This invention has particular advantages over existing systems for lining pipes of large diameters. In general, pipelining systems have used materials and lining systems suited to their application and use. Linings for gas pipes, where gas tightness is paramount, normally use standard polyethylene pipes, often temporarily deformed, to insert into old cast iron host pipes. These structural 'sliplining' techniques become impractical for large diameter pipes, say 24 inches and above, and there are no currently acceptable methods for lining larger gas pipes up to 48 inches diameter and more. For water pipes with strict drinking water regulations, cement mortar linings have been replaced by spray-on resins to prevent corrosion and leakage, whereas polyethylene sliplining techniques are used for long term structural solutions. Cured-in-place polyester resin linings are popular for gravity sewer pipes where host pipe deformity is a problem and regulation less restrictive. Again, in both the water and sewer pipe industries, the lining of large diameter pipes present difficult problems and new or alternative solutions would be welcome.

The invention uses thermoplastic extruded sheet supplied on a roll which is readily available at low cost and comes in a variety of widths up to 9m and thickness up to 100mm. Two forms of sheet are referred to in the text as 'thermoplastic sheet', which is relatively thin and wide, and 'thermoplastic strip', which is relatively thick and narrow.

This invention provides a means of lining a pipeline with a composite liner made from a seamed tube of thin thermoplastic sheet, to provide a gas or liquid tight inner seal, bonded to an outer spiral wound thermoplastic strip, to give structural properties to the lining. These structural properties can range from a simple support backing, bonded to the thin inner seal in contact with the gas or liquid, to a fully structural liner capable of meeting operational specifications without the help of the host pipe. Installation of the basic materials for this composite structure is through a relatively small access pit at each end of the pipe section to be lined. After preparation of the host pipe, a long length of thermoplastic strip, with a width less than the internal diameter of the host pipe and thickness dictated by the structural requirements, is fed from a roll through a twisting unit, situated in the access pit, and then winched

through the pipe to a spiral installation rig working back from the far end of the pipe. The installed strip normally forms a tight spiral fit inside the host pipe with each turn lying in contact with its neighbour without the need of jointing or bonding. Normally a second spiral strip will be installed in the pipe with the opposite twist to complete the structural part of the composite liner. This would be followed by the insertion of thin thermoplastic sheet from a roll with a width greater than internal circumference of the pipe to be lined, through a tube folding unit situated in the access pit, to form an overlapping tube that is winched through the pipe to be lined. The final lining operation is the seam bonding of the sheet tube and the bonding of the sheet tube to the underlying spiral lining.

The preferred method of bonding the composite pipe components is by infrared. This is carried out by an air pressurised rig that travels along the inside of the pipe and expands the liner components tightly onto the inside wall of the pipe. The rig is fitted with a infrared lamps which radiate short wave infrared energy though the thin inner sheet tube to weld the overlapping seam and also selected areas of the tube to the underlying spiral winding. For this welding process to be successful the liner materials have to have certain properties as explained in the next paragraph.

Many thermoplastic materials in thin sheet form, such as natural polyethylene, are partially transparent to short wave infrared radiation in their natural state but can be made opaque to infrared when coloured, preferably black, by dye, ink or with embedded particles or fibres made from absorbing materials such as carbon. Short wave infrared radiation, which avoids the peak absorption spectra of many thermoplastics, passing through a transparent sheet in pressure contact with a underlying sheet with opaque material at the interface will weld the sheets together by virtue of the heating and melting of the opaque material at the interface. Also, because the transparent thermoplastic material absorbs some of the infrared energy, it will warm up and soften allowing it to form to shape under applied pressure. Therefore, the favoured material for the composite liner is polyethylene where the spiral layers are made from black polyethylene and the sheet tube layer made from natural polyethylene with a black edge for the under surface of the overlapping seam.

From a pipe lining perspective a useful feature of the infrared welding process described in the previous paragraph is the distinctive change of colour, from a light grey to dark grey as seen from within the pipe, due to the surface wetting effect of the molten plastic at the interface during welding. This colour change provides an important means of verification that the weld and lining process is complete.

An alternative method of bonding the composite pipe components is by ultrasound. This is also carried out by an air pressurised rig that travels along the inside of the pipe and expands the liner components tightly onto the inside wall of the pipe. The rig is fitted with a ultrasonic welding tools which radiate ultrasonic vibrations though the thin inner sheet tube to weld the interface in the overlapping seam and the interface between selected areas of the tube and the underlying spiral winding. For successful welding the liner materials must be thermoplastic in order that the ultrasonic vibrations induce a thermal rise at the bonding interface to melt and weld the component parts.

It should be noted that many pipelines are not straight and have internal irregularities such as joints, projecting lateral connections and misalignment of pipe sections. In these pipes thin walled liners made from flat sheet will often tend to kink or buckle when forced by a pressure to deform to the internal shape of the pipeline. In a pipeline with many irregularities it is particularly difficult to seam weld reliably when the overlapping welding surfaces are distorted prior to welding and may not be in continuous contact even under high pressure. One solution to the problem is to pre-line the pipe with a underlying relatively smooth surface which could also provide structural support to the thin walled liner. Simple spiral winding made of compatible strip has this smoothing property, together with the structural properties, especially if made into a double spiral with an opposite hand winding. Such spiral lining structures enable the firm contact to be made with the thin walled sheet tube as required by various bonding methods such as infrared and ultrasonic welding techniques. The composite liner described is therefore very flexible in its ability to overcome pipeline deformities and can adapt to some variation in diameter and straightness in the sections being lined.

Although pipelines are thoroughly cleaned prior to lining the welding surfaces of the sheet tube have to be kept clean to guarantee the quality of the welded seam. There are a number of ways to protect the cleanliness of the sheet material during the installation process. One method is to wrap the sheet tube with plastic film before the tube passes into the host pipe. This wrapping can also be used to confine the diameter of the tube to enable easy insertion into the host pipe. The wrapping can be removed by the pressurised lining rig either by bursting the wrapping or cutting it. An alternative method is to bond a protection film to bridge across the edges of the sheet tube prior to insertion into the host pipe. This method completely protects the seam welding surfaces since the film can be left in place during the welding process.

Calculations show that composite polyethylene liner comprising spiral and sheet layers have a pressure capability only a few percent less than the equivalent standard pipe with the same wall thickness. The flexibility of the composite structure allows it to be reinforced with alternate or additional spiral layers wound with other materials such as high performance plastic, fibre reinforced thermoplastic, filament woven braid or metal strip. This choice of spiral strip materials enables linings to be designed to a much higher specification than standard pipes or relining pipes.

An alternative to the seamed sheet tube internal lining is to insert an extruded thin wall thermoplastic pipe into the pipe being lined and bond this to the underlying spiral wound layer in the same manner as the seamed tube. This thin walled tube could be supplied in lay flat form on a roll, inserted in a folded form and expanded to fit the lining by the pressurised welding rig.

An alternative to the structural spiral layers is to insert short lengths of thick walled pipe section in various folded forms to enable them to pass down the pipe on a travelling rig that will insert them to provide a continuous pipe lining run. These sections will be bonded to the thin sheet lining to give a composite structure with a pressure equivalent to standard pipes.

The preferred embodiments of the invention will now be described with reference to the accompanying drawings in which:

FIGURE 1 shows a cutaway view of a preferred configuration of the composite liner within the host pipe.

FIGURE 2 is a cross section of a structural configuration of a composite liner.

FIGURE 3 is a cross section of a semi-structural configuration of a composite liner.

FIGURE 4 is a cross section of a structural configuration of a composite liner with leak detection facility.

FIGURE 5 is a cross section of a structural configuration of a composite liner suited to lining pipes with severe deformities.

FIGURE 6 shows the installation arrangement to feed and twist the thermoplastic strip into the pipeline.

FIGURE 7 shows the spiral lining arrangement using a spiral installation rig within the pipe.

FIGURE 8 shows the installation arrangement to feed and form the thin thermoplastic sheet into a rolled up tube that is winched through the pipe.

FIGURE 9 shows the travelling welding rig which expands the rolled up sheet tube, welds the lining seam, and welds this lining onto the underlying spiral wound lining.

FIGURE 10 shows detail of the seam welding arrangement.

Figure 1 shows a cutaway view of a preferred configuration of the composite liner within the host pipe 1. A thermoplastic strip forms a spiral lining 2 tightly wound onto the inside surface of the pipe with each turn in contact with the neighbouring turn. Inside this lining there is a second spiral strip lining 3 again tightly wound onto the inside surface of the first lining but wound in the opposite direction. These freely wound spiral layers form a stable structural assembly held in place by the host pipe. However, the structure is not gas or water tight and hence an inner liner 4 comprising a seamed thermoplastic tube is bonded to the inner surface of the spiral structure. The structural qualities of this composite lining compare to standard thermoplastic pipes of similar wall thickness and the flexible design using basic materials lends itself to the lining of large diameter pipes.

Figure 2 shows a cross section of a host pipe 1 with a thin seamed tube inner lining 4 backed by two thick spiral wound strip linings 2 & 3, wound in opposite directions, to give a composite liner that has sufficient structural strength to be used either, as a semi-structural lining that reinforces the host pipe to give a structural combination equivalent to a standard pipe or, as a fully structural lining that can match the pressure specification of standard pipes of similar wall thickness. Typically, a pipe lining with a 17.6 SDR (standard dimensional ratio) would be 600mm diameter, 34mm wall thickness made up of two spiral layers of 15mm thick each and a sheet tube layer of 4mm thick.

Figure 3 shows a cross section of the host pipe 1 with a thin seamed tube inner lining 4 backed by one thick spiral wound strip lining 2 to give a simple composite liner. This configuration is gas and liquid tight and has sufficient structural rigidity to support itself within a pipe or if necessary resist external pressure due to water or gas ingress.

Figure 4 shows a cross section of the host pipe 1 with a thin seamed tube inner lining 4 backed by two thick spiral wound strip linings 2 & 3 together with a thin seamed tube outer lining 5 to give a composite liner that can have sufficient structural strength to match the pressure specification of standard pipes of similar wall thickness. This configuration can also provide the means of detecting gas or liquid leakage through the liner by monitoring the pressure or flow in the space between the inner and outer seamed tube linings. This is due to the enclosed porous spiral structure that allows leaking gas or liquid to flow along the length of a lined pipe section.

Figure 5 shows a cross section of the host pipe 1 with a thin seamed tube inner lining 4 backed by two thick spiral wound strip linings 2 & 3 together with a thin seamed tube outer lining 5 and a thin seamed tube intermediate lining 6 to give a composite liner that can have sufficient structural strength to match the pressure specification of standard pipes of similar wall thickness. This configuration helps to provide smooth internal surfaces to enable gas and water tight welding when the host pipe suffers severe deformities.

Figure 6 shows a roll of thermoplastic strip 7 of a preferred width approximately equal to half the diameter of the host pipe 1 and a thickness dictated by the lining specification. The strip is drawn into the exposed pipe end in the access pit 8 by a winch, at the far end of the pipe section to be lined, and twisted into stretched helix 9 by rotating the roll 7 and associated guide rollers 10 about the bearing 11 fixed to the supporting stand 12. If the strip needs extending a new roll can be installed and the strip fusion bonded to the tail end of the previous roll using standard techniques. When the strip reaches the spiral winding rig (see Figure 7), initially located at the far end of the pipe, the feed from the roll is held until the rig is ready to line the pipe. This spiral winding rig then draws further twisted strip from the roll to line the pipe and effectively consumes one twist of the strip for every spiral turn carried out by the rig.

Figure 7 shows the spiral winding rig 13, held by a control winch, used to line the pipe with thermoplastic strip fed by the installation rig described in Figure 6. The twisted strip 9 is drawn through guide rollers 14 into a freely rotating rig 13, on guide wheels 15, inside the host pipe 1 and fed by powered 16 pinch rollers 17 to create a spiral lining 18 on the inside wall of the host pipe. Suitable guides are provided inside the rotating rig 13 to translate the stretched helical twist 9 in the incoming strip to the tight helical feed required to line the pipe. The lining process requires careful control of the longitudinal travel, by means of the winch and strip tensions, and the feed direction of the pinch rollers 17. Mechanical and electrical sensing of the edge of the previous spiral turn can provide the means of such control. Reaction on the pinch rollers by the spiral winding action forces the freely rotating rig 13 to both turn and travel down the pipe until the lining process is complete.

Spiral winding of strip with a normal rectangular cross section causes a distortion of the cross section of the strip normally identified by edge turn-up. This causes a uneven inner surface of the spiral lining which is undesirable but not detrimental. Solutions are to feed the strip through profiled powered pinch rollers either when leaving the roll or in the spiral winding rig in order to induce a compensating lateral curvature.

The equipment described in Figures 6 and 7 wind a clockwise spiral as seen from the strip feed end. The equipment is easily reversible in order to wind neighbouring spiral layers in an anti-clockwise direction.

Figure 8 shows a roll of thermoplastic, normally polyethylene, sheet 19 having a required width to cover the internal circumference of the host pipe plus some overlap. For welding by infrared the material is natural coloured, to enable infrared transmission through the sheet, with one edge of the sheet coloured black, to enable infrared absorption at the interface and hence heating and welding. The width of the roll, say 3.5m for a 1m diameter pipe, may be too wide for a practical access pit and therefore the roll may need mounting above ground. This means the sheet feed has to curve into the access pit to line up with the exposed pipe without kinking during formation of lining tube. The solution to this problem is to fold the sheet into a flattened tube to enable it to bend about the wide axis whilst minimising the distortion of the sheet. In the figure the sheet 20 is fed from the roll 19 through guide rollers 21 to series of guides and rollers 22 to turn up the edges of the sheet 23 and then fold them over to make a flat tube 24. The formed sheet 24 has its total width reduced and fits into a access 25 of more practical dimensions. The flat tube cross-section can now be curved through a series of rollers 26 and low-friction guides into a horizontal direction. To help to maintain the sheet profile without kinking around the curve an internal tongue 27 is fitted and held by a support through the slot at the top of the flat tube. Further rollers 28 and guides help the flat tube to expand into a round tube 29 as it enters the end of the host pipe 1 taking care that the natural coloured material overlaps the black edge as seen from inside the tube. A winch located at the far end of the pipe provides the force 30 required to pull the sheet through the forming rig and along the pipe. If it is required to keep the sheet lining tube clean a plastic film wrapping can spun around the sheet tube as it enters the host pipe. This can be burst by the rig air pressure or cut by an attachment on the lining rig, shown in Figure 9, to allow the tube to expand into contact with the pipe wall.

Figure 9 shows a lining rig 31 designed to complete the lining process by seam welding the sheet tube 32 to form a gas and liquid tight inner lining. At the same time the rig welds the sheet lining to the underlying spiral lining. The rig is pulled along the pipe at a controlled rate by a winch located at one end of the pipe section to be lined. Behind the rig the lined host pipe is pressurised by a fan installed in a sealed stop at the starting end of the pipe. The lining rig 31 has an air tight front shield 33 and the air pressure drives the rig along the pipe at a velocity controlled by the winch feeding out cable 35. The air pressure forces the lining components tightly onto the host pipe wall, ensures the welding surfaces are kept in pressure contact during welding, and prevents any distortion of the lining during welding and cooling. The rig 31 runs on two sets of radial wheels 36 and supports a number of welding boxes 37 containing the preferred infrared lamps. These welding boxes 37 can rotate on the bearing 38 to allow the seam welding box to follow the seam along the pipe using

mechanical or electrical sensors. The other welding boxes, often 4 to 6, can weld the sheet tube, either as a continuously a line weld or intermittently to create a spot weld pattern, to the underlying layer of black spiral strip. Cooling of the welding operation is provided by allowing some air 39 to bleed through the welding boxes and rig members to the low pressure side of the shield. Weld verification is carried out by onboard CCTV cameras or by later inspection. Good continuous welds are indicated by distinctive colour change of the welded area. On completion of the lining process, purpose made couplings are connected or fusion welded to the ends of the lining and the lined section pressure tested and leak tested in accordance to gas or water regulations.

Figure 10 shows an infrared welding box 37 used to weld the overlapping seam of the preferred polyethylene sheet tube. The host pipe 1 is lined by two spiral strip layers 2&3 and the sheet tube layer 4 with the overlap 40. The lower overlap surface has a black polyethylene surface 41 to absorb the infrared that penetrates through the upper natural polyethylene overlap sheet to heat, melt and weld the interface. The welding box 37 is mounted on the guide arm 42 and contains the infrared lamp 43 that provides the infrared radiation. Figure 10 also shows two of the infrared welding boxes 44 that weld the seamed sheet tube to the underlying black spiral layer. Normally there will be 4 to 10 boxes, depending on the diameter of the pipe, equally distributed around the inside circumference of the lining. These boxes can weld either a line weld or spot weld as the lining rig travels along the pipe.

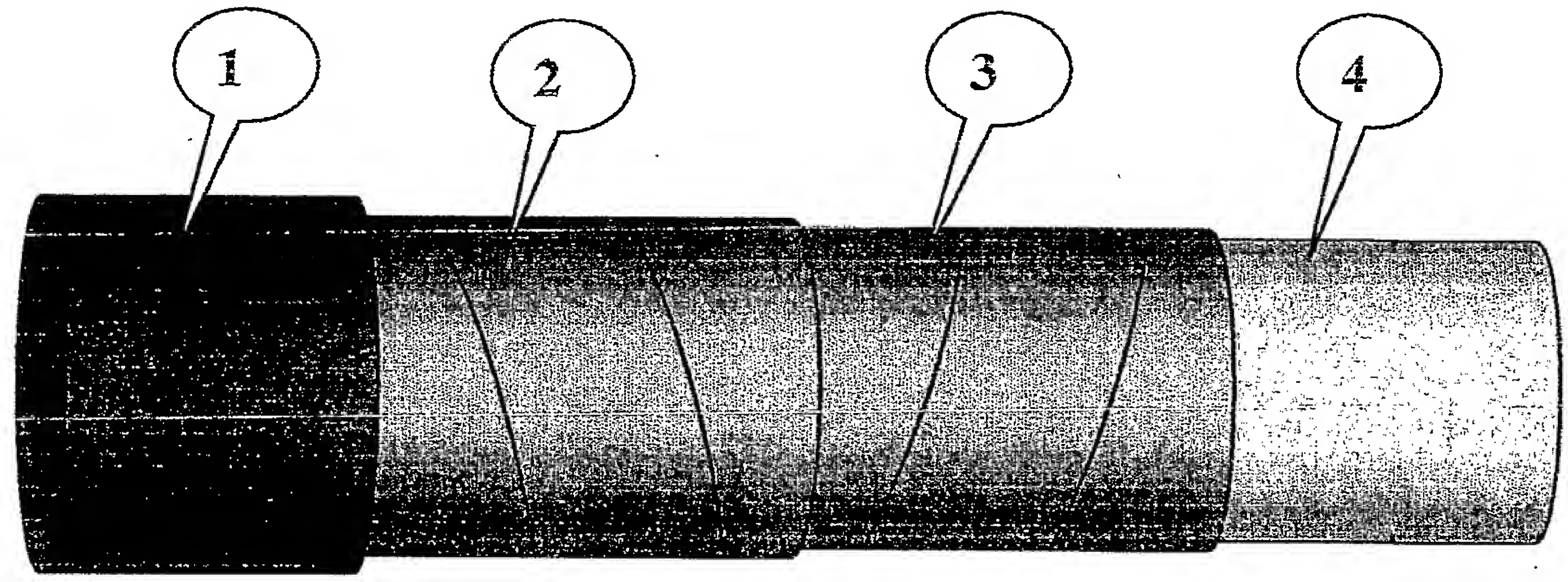

Figure 1

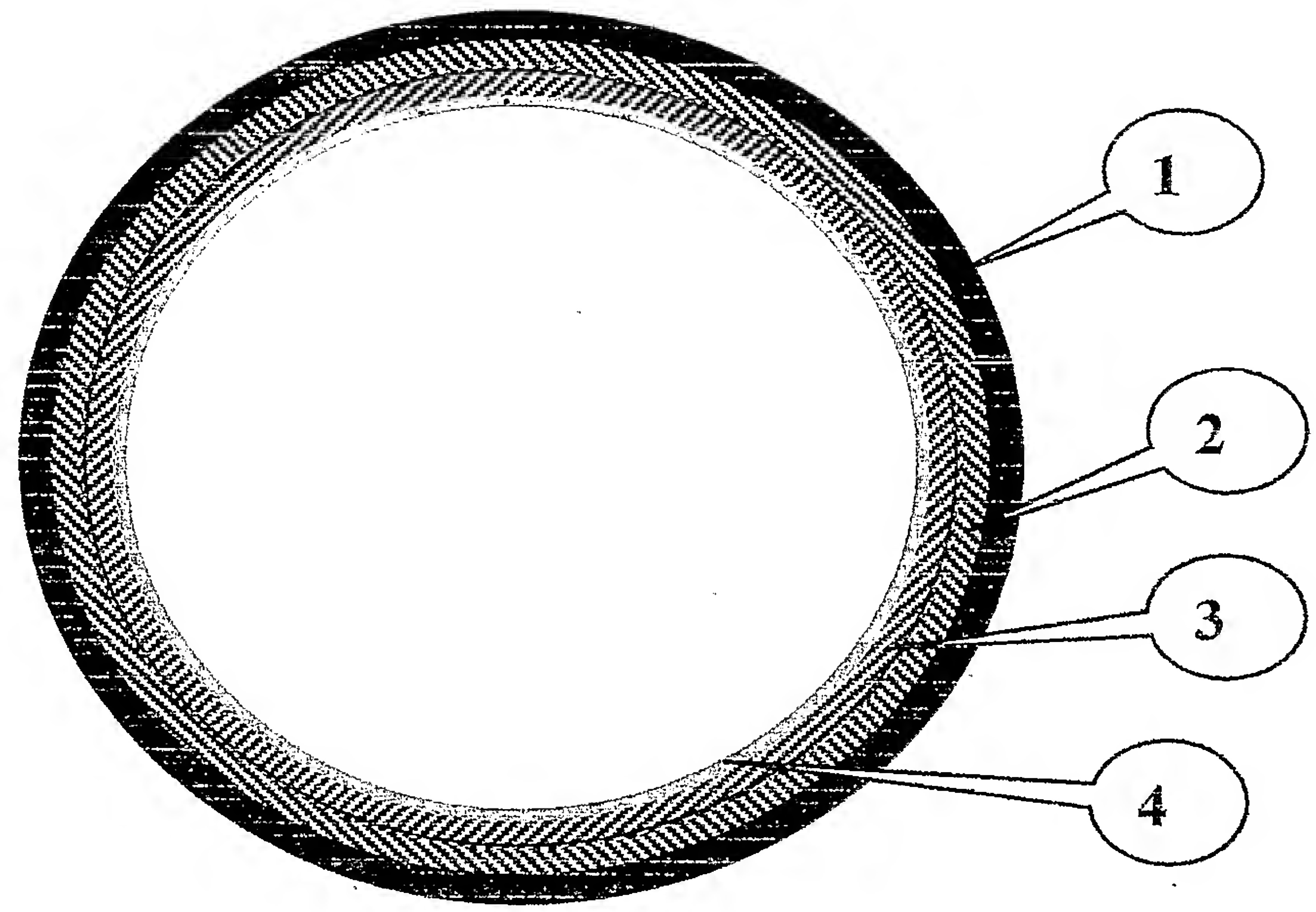

Figure 2

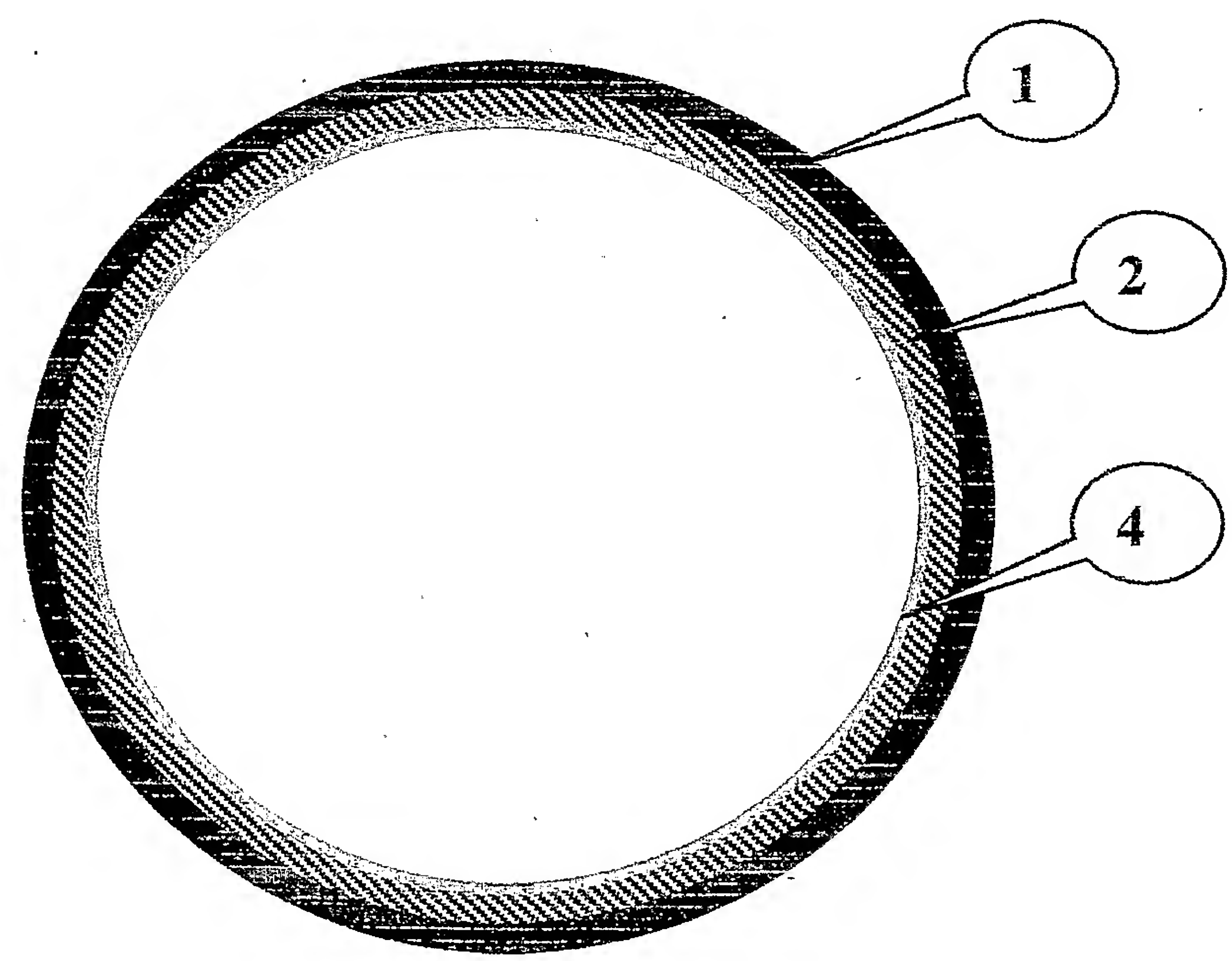

Figure 3

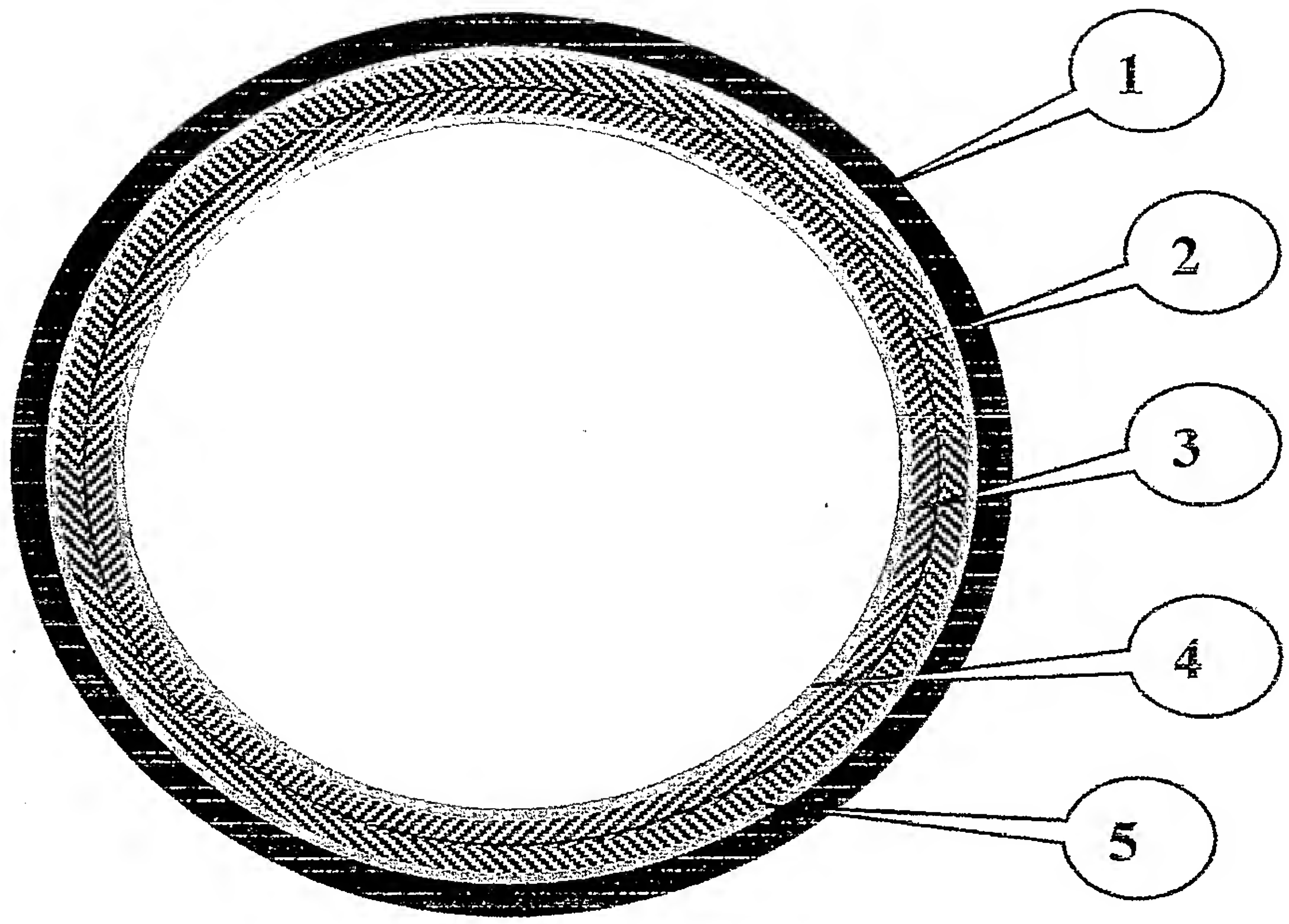

Figure 4

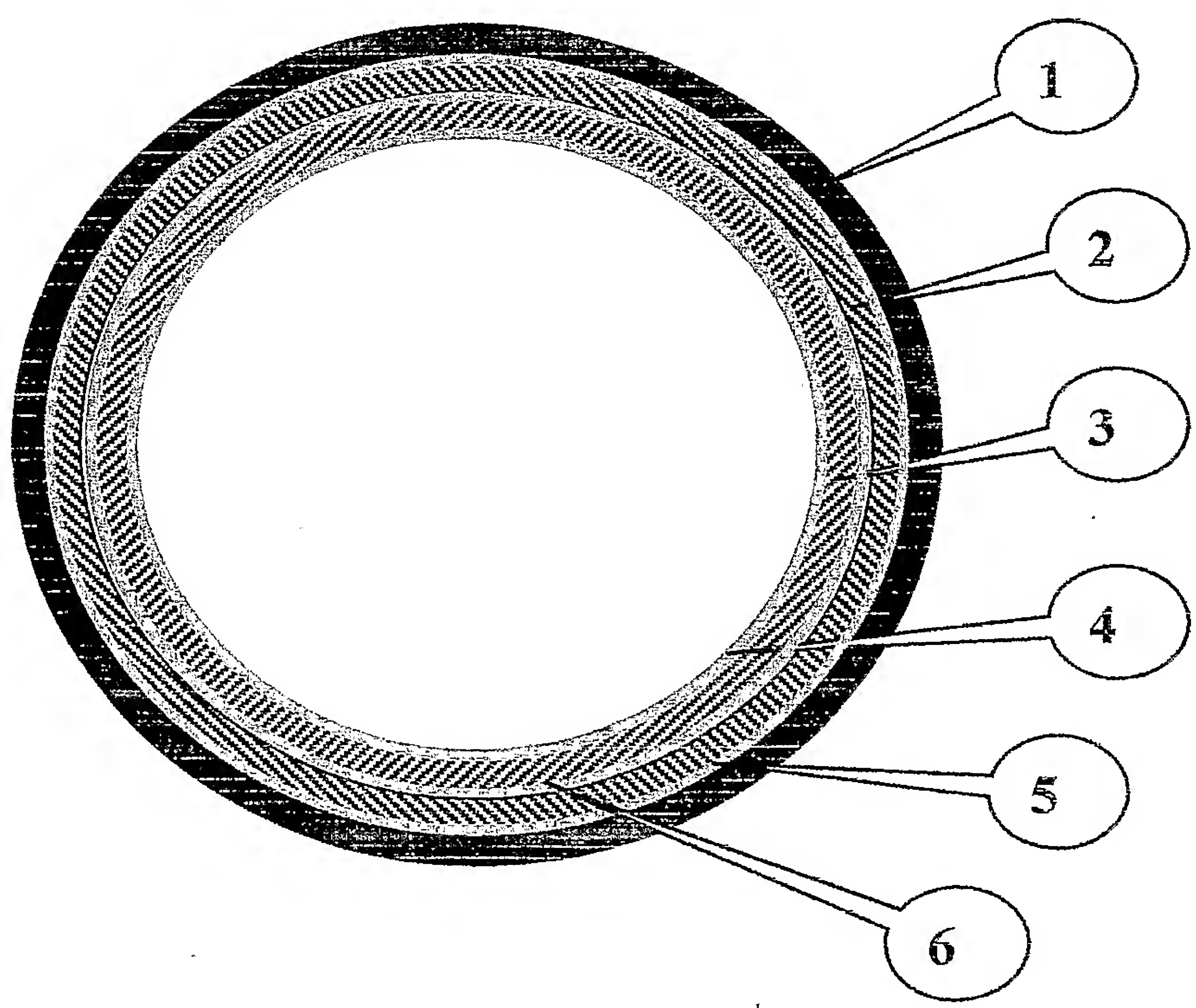

Figure 5

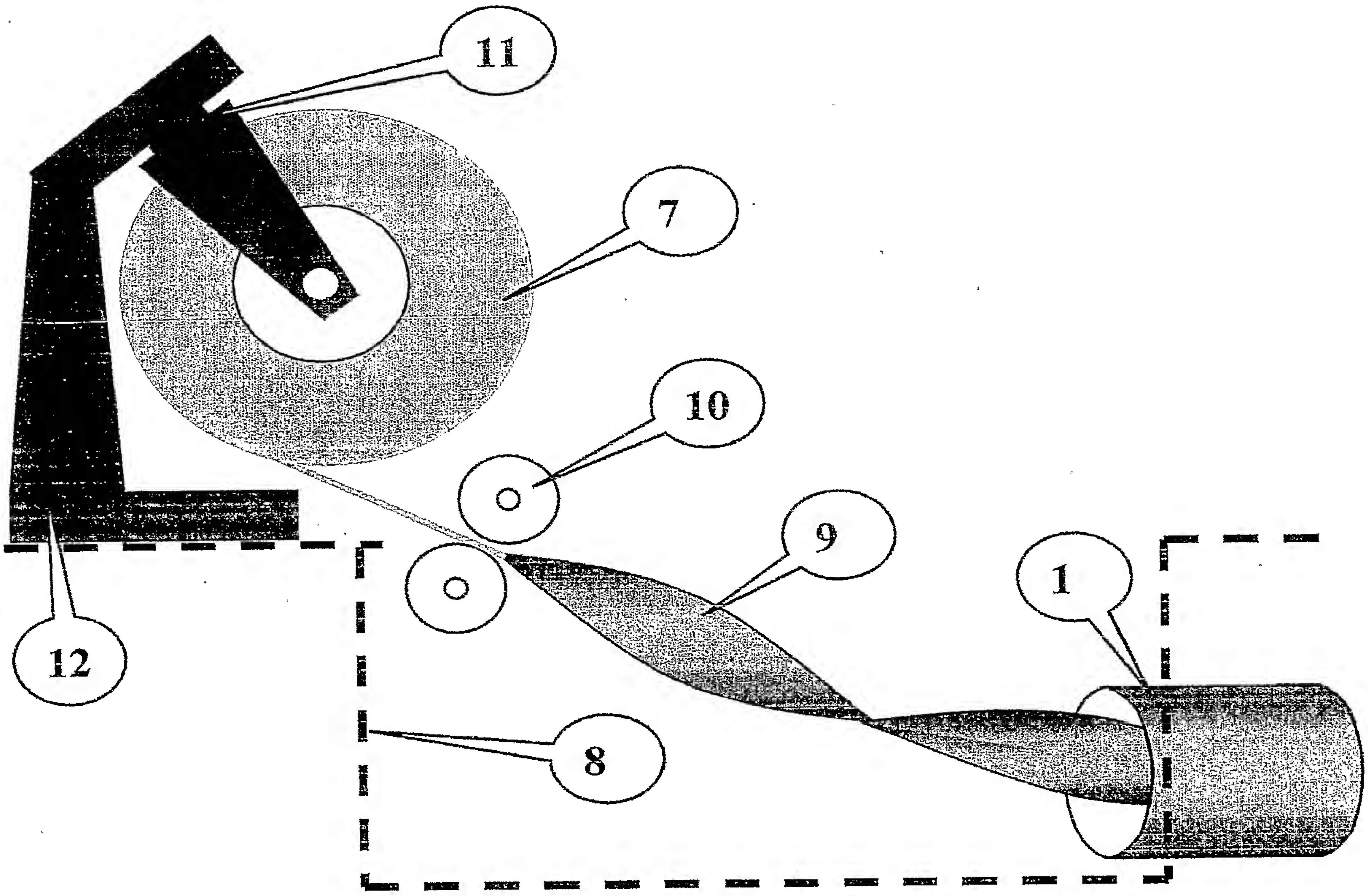

Figure 6

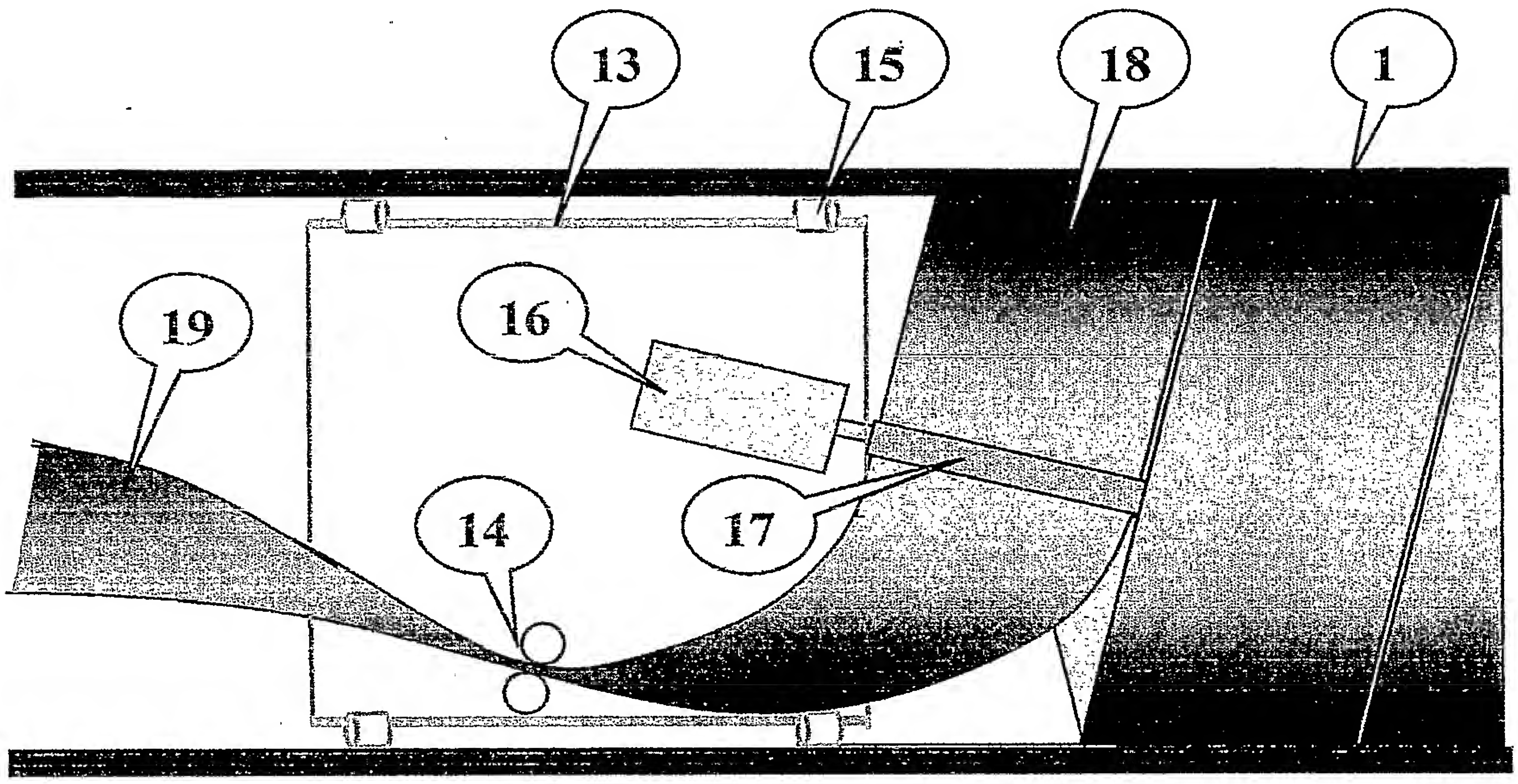

Figure 7

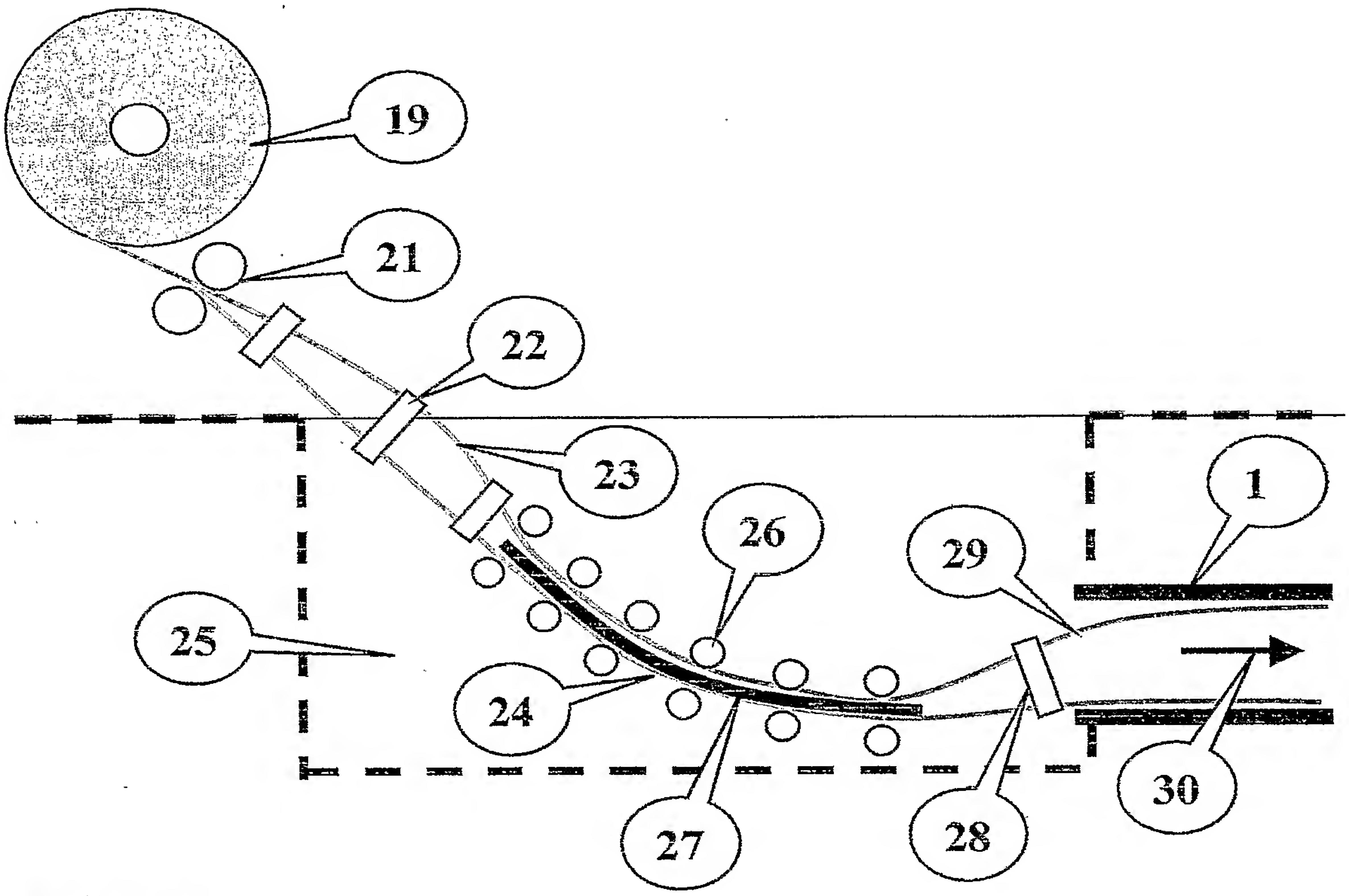

Figure 8

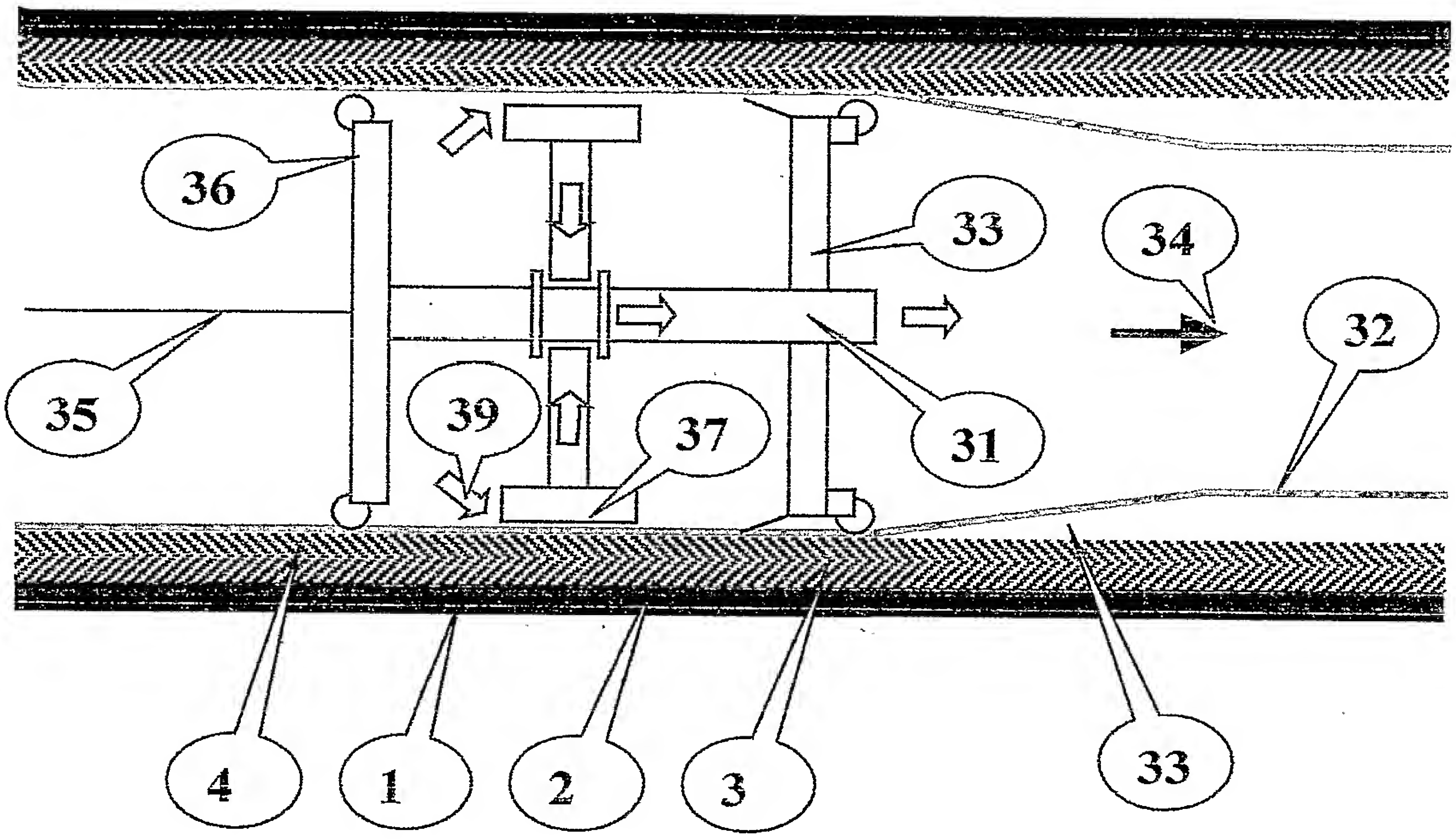

Figure 9

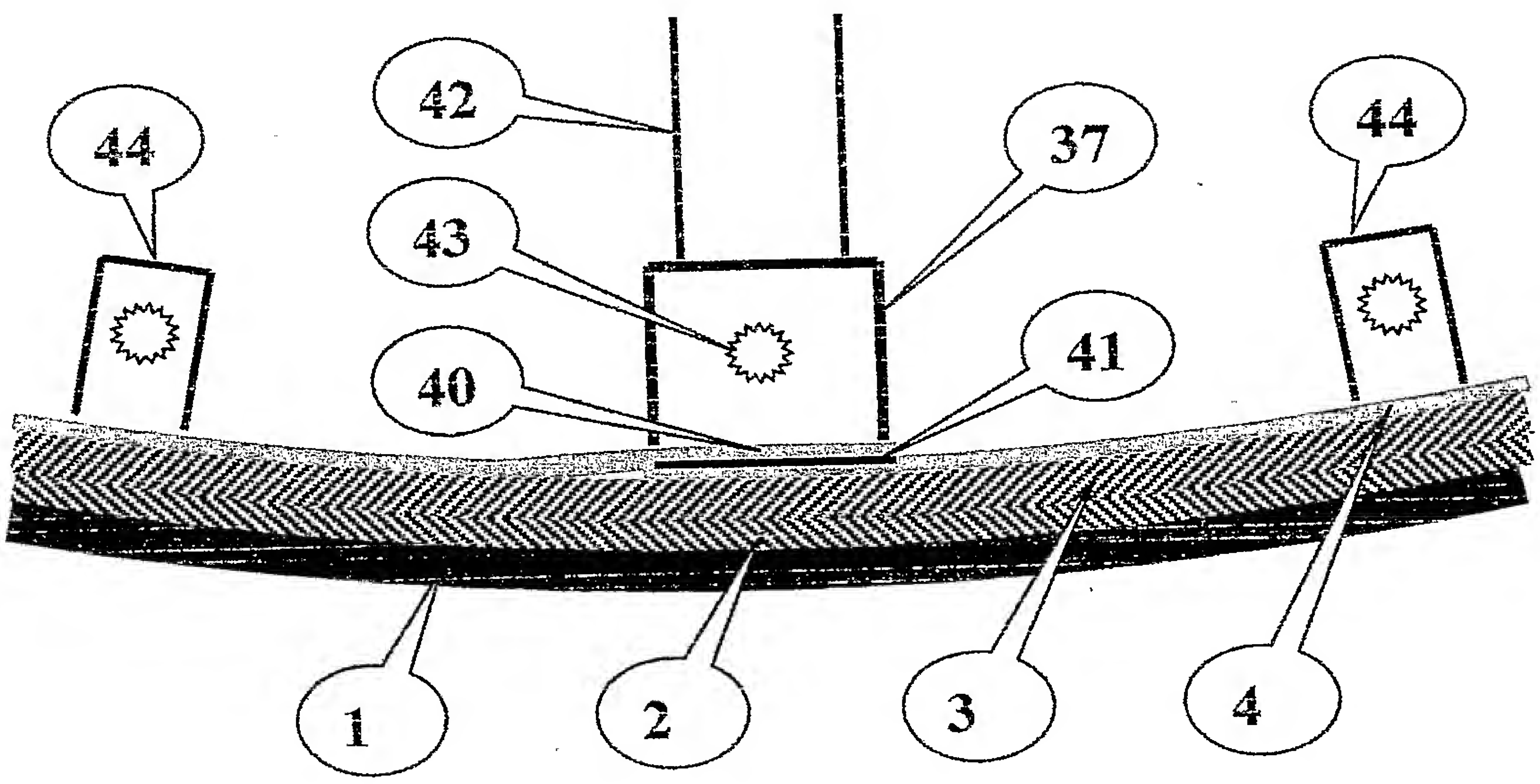

Figure 10